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Summary of Section 11, Salinity Impacts

Purpose:

Section 11 describes the Water Analysis Module (WAM), the simulation model used to assess the effect of levee failures in the Delta on water quality (as measured by salinity levels).

Methods of Analysis:

A given levee breach scenario considered in the risk analysis is identified and specified by the modules discussed in previous sections: seismic or flood hazard, levee vulnerability, and emergency response. WAM receives the specifics of the breach event as input and simulates the direct, salinity-related consequences of the event. WAM incorporates initial island flooding, upstream reservoir management response, Delta water operations, salinity disruption of Delta irrigation, Delta net water losses (or net consumptive water use), hydrodynamics, Delta water quality (represented by salinity), and water exports as impacted by salinity. WAM produces hydrodynamic, water quality (salinity), and water supply consequences for use in the economic and ecosystem modules. It was necessary to develop WAM as a new and innovative simulation model to include interactions of a levee breach event with water operations (e.g., upstream reservoir releases) and to achieve reduced computation times (minutes rather than days) so may scenarios can be simulated.

Main Findings:

Figures 11-8 and 11-9 demonstrate that WAM is able to respond to and represent dramatic changes caused by levee breaches in the variety of situations presented by various months of the year and in years of varying degrees of wetness or dryness. Figures 11-11 and 11-12 demonstrate how WAM both addresses a wide variety of hydrologic conditions and covers the spectrum of available hydrologic data with computational efficiency. A 5-year WAM simulation for a specific levee breach and start time takes less than 5 minutes to run, so it is possible to perform hundreds or thousands of simulations. In comparison, the models used before the Delta Risk Management Strategy project required several days to complete a simulation of a single levee breach event and start time. Therefore, WAM was used to simulate tens of thousands of levee-breach / start-time combinations to provide the needed variety of inputs to subsequent modules of the risk analysis—primarily the economic module. Figure 11-10 demonstrates that the simplifications incorporated in WAM (tidal averaging and one-dimensional geometry) still maintain an acceptable degree of accuracy when comparing a WAM simulation result (with no levee breach) with measured historical conditions. Thus, WAM provides the key link for assessing what a levee breach event would do to Delta salinity and what disruptions this result would have on Delta water uses.

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One or more levee breaches in the Sacramento–San Joaquin River Delta (Delta) that result in island flooding may impact Delta water quality (most obviously salinity) and water operations. A substantial amount of saline water may be drawn in from the Bay—depending on the initial salinity of the river/Delta/Bay system; river inflows at the time of the breach event; and the number, size, and locations of the breaches and flooded islands. Subsequently, salinity may be dispersed and degrade Delta water quality for a prolonged period due to the complex interrelationship between ongoing Delta inflows, tidal mixing, and the breach repair schedule. Other water quality measures, such as organic carbon, are also important. However, the essential first step in characterizing Delta water quality, in context of a levee breach event, is to characterize salinity.

Tracking of any contaminant in the Delta waterway system is dependent on first being able to accurately simulate the movement and mixing of Delta waters – that is, Delta hydrodynamics. Salinity is the obvious marker for tracking the movement and mixing of Delta waters. It is ubiquitous, easily measured, and exhibits strong variations due to the low salinity of freshwater inflow, the high salinity of Bay waters, and the strong tidal hydrodynamic movement and mixing. Unless salinity movement, mixing and resulting concentration gradients can be accurately represented, a model will not be able to track the movement, mixing, and concentration variations of any other contaminant. Modeling salinity is the essential first step and is the only water quality parameter used for the Delta Risk Management Strategy (DRMS) Phase 1 risk analysis.

A given levee breach scenario considered in the DRMS risk analysis is identified and specified by the modules discussed in previous sections – seismic or flood hazard, levee vulnerability, and emergency response. The Water Analysis Module (WAM) receives the specifics of the breach event as input and simulates direct, salinity-related consequences of the event. Specifically, WAM incorporates:

- Initial island flooding
- Upstream reservoir management response
- Delta water operations
- Salinity disruption of Delta irrigation
- Delta net water losses (or net consumptive water use)
- Hydrodynamics
- Delta water quality (initially represented by salinity)
- Water exports as impacted by salinity

The module is central to the risk analysis, as illustrated in Figure 11-1, receiving the description of each breach scenario (e.g., resulting from a seismic or other event) and the details of the levee repair process from the emergency response and repair part of the analysis. The model produces hydrodynamic, water quality (salinity), and water supply consequences for use in the economic and ecosystem modules. The water quality consequences of levee failures in the Delta are dependent not only on the initial state of the Delta at the time of failure, but also on the time series of tides, inflows, exports, other uses, and on the water management decisions that influence these factors. Thus, WAM is the model that tracks water management and the Delta's water quality response starting before the initial breach event and proceeding through the breach, emergency operations, repair, and recovery period. The model is a key link in facilitating assessment of ecosystem and economic consequences and associated risks.

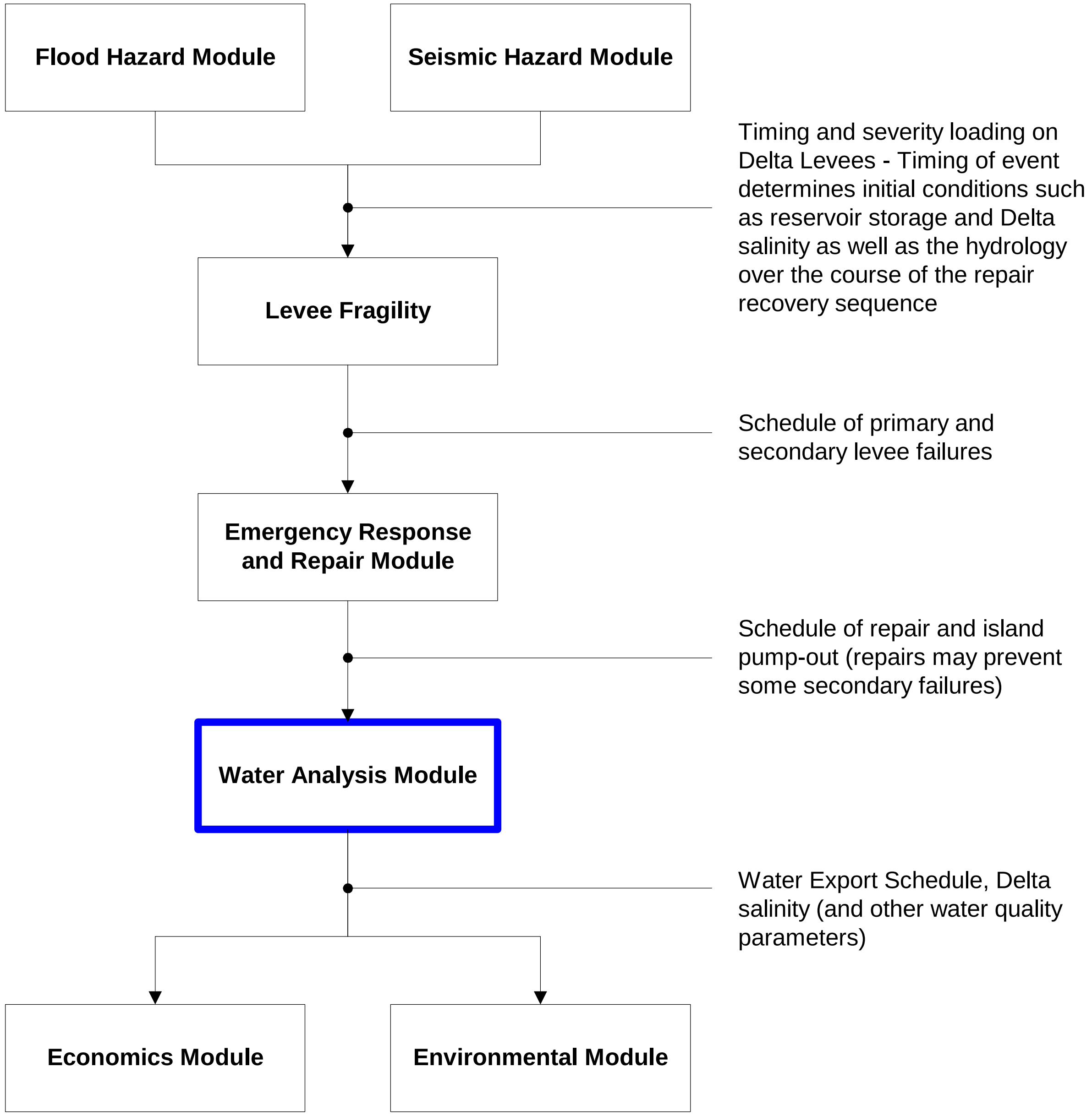


Figure 11-1 Position of the Water Analysis Module in the Risk Analysis Framework

The Water Analysis Module Technical Memorandum (TM) (URS/JBA 2007e) presents more detailed information on the WAM and its use to estimate salinity impacts. Note that available schedule and budget have not allowed incorporation of other water quality parameters into WAM. Additional parameters, such as organic carbon, can be incorporated during a subsequent model development phase. Since organic carbon is important to urban water agencies, a preliminary analysis of potential organic carbon increases caused by contact of waters with flooded island organic soils has been provided in Appendix I of the Water Analysis Module TM

(URS/JBA 2007e). The results of the preliminary analysis indicate that increased organic carbon concentrations are potentially very significant, that organic carbon should be modeled in more detail, and that island dewatering should be managed to minimize organic carbon impacts. This effort would require extensions of both WAM and the Emergency Response and Repair Module.

11.1 OVERVIEW

11.1.1 Background

In the past, water management modeling (calculating quantities of Delta inflows and outflows) and Delta hydrodynamics/water quality modeling have usually been conducted separately. Few modeling efforts of either type have addressed levee breaches.

The models of either type that are most capable for this application tend to be elaborate and sophisticated. They would be impractical in the context of a risk analysis that is to examine many scenarios, primarily because they require large amounts of computation time.

The CalSim model (Draper et al. 2004) is the recognized state-of-the-art for simulating the translation of hydrologic inputs to the Delta tributaries into storage in upstream reservoirs, allocations for various uses, and inflows into the Delta. It is a monthly simulation model designed to use a defined development state (e.g., 2005) and to then simulate monthly water management for historical hydrologic inputs (1922 to 2003).

CalSim bases its management on the need to meet Delta water quality standards by including an Artificial Neural Network feature that is trained to estimate required Net Delta Outflow using a California Department of Water Resources (DWR) Delta salinity model (the Delta Simulation Model 2 [DSM2]) for the normal Delta configuration (no levee breaches). It has no present ability to represent Delta levee breaches. It is useful for DRMS as a base case, with no breaches (see URS/JBA 2007e, Appendix C).

Several hydrodynamic models of the Delta can be used to simulate its hydrodynamic interaction with freshwater inflows and San Francisco Bay's tidal action and salinity. Model outputs generally include time varying flows and salinity at selected stations in the Delta. The models include DSM2 (DWR 2008), which is a one-dimensional model (including tidal movements), the RMA Bay Delta model (see URS/JBA 2007e, Appendix D), which is a two-dimensional (depth averaged) model (including tides), and TRIM and UnTRIM (see URS/JBA 2007e, Appendix H), which are three-dimensional models (including tides).

Each of those models simulates Delta hydrodynamics on a short time interval (e.g., 7.5 minutes) and relatively fine spatial grid so that it captures tidal variations. This requires the models to use large amounts of computer time for any one scenario, especially if it requires several years of simulation.

The RMA Bay Delta Model has previously been used to represent Delta levee breach events (JBA 2005). However, as described in the Water Analysis Module TM (URS/JBA 2007e, Appendix D), even with this capability, the RMA Bay Delta Model is too computationally intensive and its best use is for calibrating a simpler, more-efficient model.

Similarly, the three-dimensional models are used for calibrating simpler models. A key simplification adopted in WAM is to use a tidally averaged model and include the effects of tidal mixing through the use of dispersion coefficients.

In the prior assessment of risks to water quality and water uses from Delta levee failures (JBA 2005), the RMA Bay Delta model was used, but only two scenarios were simulated – a 20–islands-flooded case and a 19-islands-flooded case (where Sherman Island was assumed to be hardened so it was no longer seismically vulnerable).

Only one earthquake and event initiation time was considered: July 1, 2002. In the present case, DRMS requires consideration of many other failure scenarios and different start times for each.

Also, historic Delta inflows were used in the previous study. This was a convenient assumption for a preliminary analysis, but it is recognized that an effort will be made to adjust upstream reservoir releases to flush salinity and reestablish fresh conditions for in-Delta water use and exports, providing sufficient stored water is available. This will require new simulation capabilities as well as decreased computation time.

11.1.2 Objectives

The following are the objectives established for the Water Analysis Module:

- WAM must provide simulation results (water storage and flows and Delta salinity throughout the event) for a wide variety of levee breach events – results that are adequate to characterize economic and environmental consequences, including salinity impacts on in-Delta irrigation and state and federal water exports.
- WAM must be practical (computationally efficient) for evaluating many (potentially thousands of) levee failure scenarios – that is, various combinations of flooded islands and various event initiation times associated with different seasons and hydrologic conditions.

11.1.3 Approach

Because a complex interrelationship exists between reservoir operations upstream of the Delta, hydrodynamics and water quality within the Delta, and the ability to use or export water from the Delta, these features of WAM within the risk analysis framework are combined into a single module. When an emergency occurs, decisions will be made to manage ongoing reservoir releases and Delta exports based on the water quality of the Delta, so it is not possible to set release or export strategies without considering the evolution of Delta water quality. In WAM, water quality conditions are initially represented by salinity; other measures of water quality can be added later, if desired.

The decision submodels incorporated into WAM calculate Delta water operations, upstream reservoir releases, and exports immediately after a breach event and throughout the repair/recovery period. The decision submodels are based, to the extent possible, on operating rules included in existing models of the California water system, water rights, water quality standards, contractual requirements, and operating guidelines.

CalSim is an example of an existing model that includes operations components. However, because it does not consider levee breach emergencies, different operating rules than those currently included in CalSim are required to manage water operations in response to such an emergency. Considerable input was required from operators and policy makers responsible for managing the state and federal water systems to develop the decision submodels. The initial versions of the models reflect this input, but the amount of input was constrained by the limited schedule and budget. Additional input is needed and will be reflected in future versions of the models.

The overall WAM simulation of a levee breach scenario has been subdivided into three phases, as illustrated in Figure 11-2, to reflect the dramatically different hydrodynamic and water management situations that define each phase. The phases in WAM simulation can be described as follows:

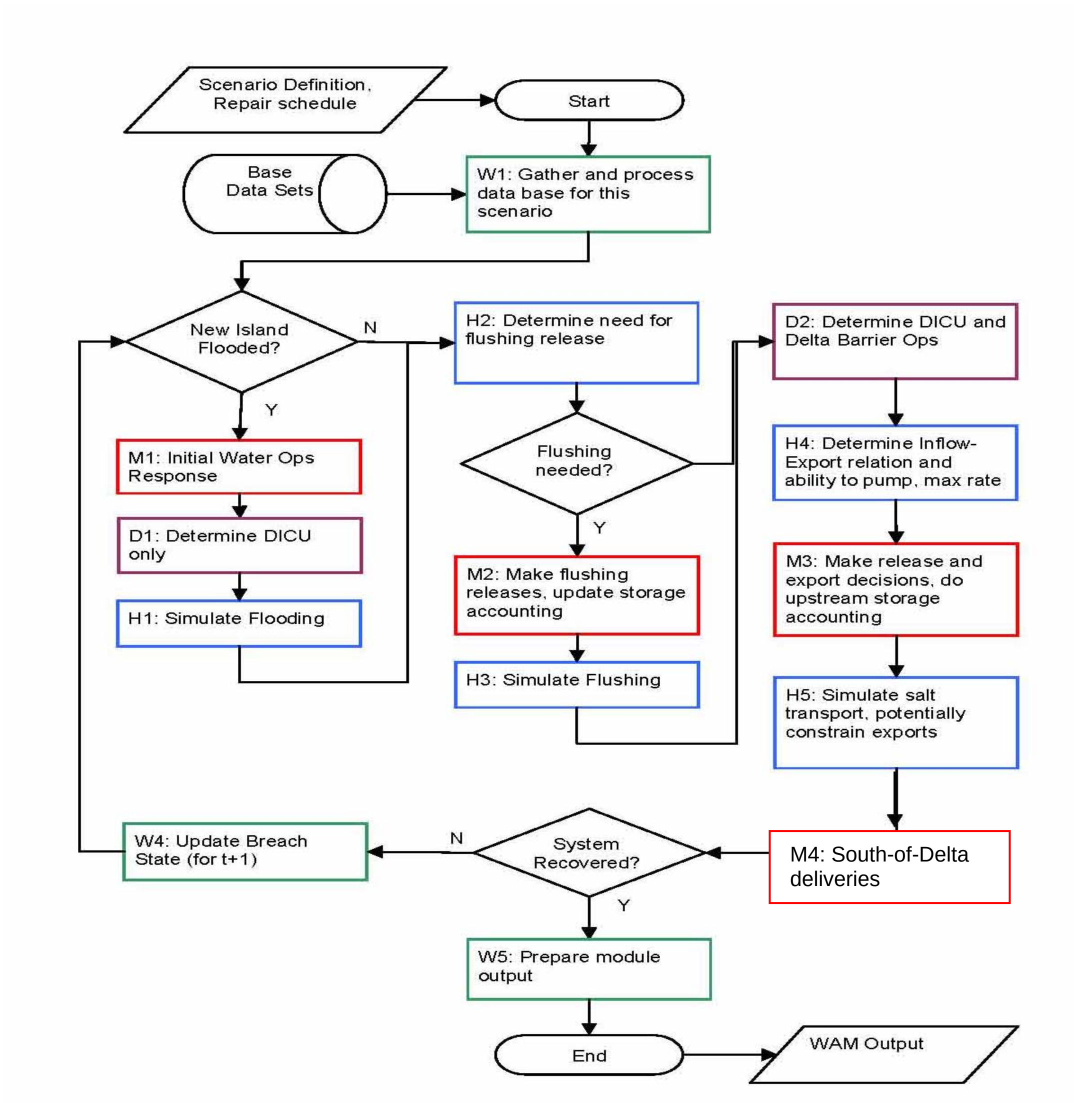


Figure 11-2 Schematic of the WAM Calculations

- **Island Flooding (on the left in Figure 11-2) –** The rush of water filling an island(s) immediately following a levee breach will often dominate Delta water flow or hydrodynamics (especially in the dry season or after multiple, approximately simultaneous levee breaches). Island flooding may take up to several days. The water needed to fill the islands comes initially from adjacent Delta channels, but the effect will be felt at an ever-expanding spatial scale. Ultimately, the total volume required to fill the islands and restore overall balance will come from river inflows and/or flow from Suisun Bay.

  The hydrodynamics submodel considers the initial flow and salinity conditions in the Delta (as obtained from CalSim results for the selected event initiation time); calculates the sources, amounts and distribution routes of the required inflows; and characterizes the resulting Delta salinity distribution at the time a stable flow situation reestablishes (post flooding). The "flooding" phase of WAM accomplishes this modeling task.

- **Flushing (in the middle in Figure 11-2) –** During the flushing period, WAM's focus is on the Delta freshwater inflows, tidal mixing, dispersion and dilution of salinity, and the gradual movement or reestablishment of a freshwater/saline water interface at a more normal downstream location. Upstream reservoir management and flushing releases are primary considerations, and the hydrodynamics and water quality submodel is focused on characterizing the distribution and timing of water quality improvements that result from flushing.

  Pumping for export during the flushing period could exacerbate the situation by drawing saline water into the Delta. Specifically, the south Delta can be very strongly impacted by salinity intrusion. Previous modeling (JBA 2005) suggests the south Delta may experience a degraded water quality condition and prolonged disruption. Under such conditions, adverse results would include prolonged noncompliance with water quality standards for environmental (in channel) conditions, local (Delta area) uses and exports.

- **Limited Pumping (on the right in Figure 11-2) –** When Delta water quality is sufficient to allow in-Delta use and export pumping, the WAM focus shifts to maintenance of the Delta's water quality and deciding how much upstream reservoir water can be used in support of export pumping. These decisions are not straightforward. Maintaining Delta water quality when several islands are still flooded requires more than the usual inflow of freshwater because of the extra volume of tidal inflow and outflow under breach conditions (due to flow into and out of flooded islands) and the resultant increased mixing. Additionally, the amount of water required, over and above the amount of pumping to prevent quality degradation (i.e., carriage water), will also increase. If poorly considered decisions are made, the upstream reservoir storage may be significantly depleted or opportunities for additional export could be missed.

  The WAM calculator simulates these upstream reservoir operation and pumping decisions until Delta levee repairs are completed and both pumping and reservoir storage return to normal. Obviously, these decisions and the resulting Delta water quality have impacts on in-Delta uses and the ecosystem as well as exports.

WAM simulates the water-quality consequences of the levee breach occurrence, repair and water management responses, Delta inflows, Delta hydrodynamics, and water quality through time – in some cases, through an extended period of time. To avoid iteration – a computationally intensive approach – WAM calculations for the current time step rely only on the calculation results from the previous time step. Internally, WAM includes several processes (such as island flooding and Delta flushing) that must be addressed on a daily basis. Thus, a daily interval is the basic time step used. However, the overall results of Delta water quality, changes in reservoir storage, exports, and other items used to assess consequences are reported monthly.

At the daily time step, the model includes tidal averaging simplifications as an approach to achieve computational efficiency. This approach is made possible by using dispersion coefficients to capture the impacts of tidal mixing, as required for accuracy. More spatially and temporally detailed three-dimensional models (TRIM and UnTRIM) and two-dimensional models (the RMA Bay-Delta Model) have been used to calibrate the dispersion coefficients for the simpler tidally averaged one-dimensional model that is central to WAM. Details of calibration and verification are provided in Appendices D and E of the Water Analysis Module TM (URS/JBA 2007e).

The following subsections provide additional summary information on each major submodel included in WAM; further detail is available in the Water Analysis Module TM and its appendices (URS/JBA 2007e). The order of the subsections has been chosen to describe the simpler things first, since they then become inputs to the more involved hydrodynamics calculations. Thus, we present the subsections in the following order:

- Delta Water Operations
- Net Delta Area Consumptive Use
- Upstream Reservoir Operations, Target Exports, and Deliveries
- Hydrodynamics and Water Quality.

11.2 DELTA WATER OPERATIONS

In the event of a Delta levee breach resulting in island flooding, Delta water operations may be substantially altered – gate positions may be changed (including the Delta Cross Channel gates and the South Delta barriers), export pump operations may be curtailed (e.g., emergency shutdowns), in-Delta diversions may cease (for Delta island irrigation) and, potentially, upstream reservoir releases may occur to counteract salinity intrusion during island flooding. The purpose of the Delta Water Operations Submodel is to represent these operations as they are expected to occur in a BAU response to a Delta levee breach incident. This effort is necessary because they will impact Delta hydrodynamics and salinity concentrations. Details are presented in Appendix B of the Water Analysis Module TM (URS/JBA 2007e).

The operations submodel is subdivided into three phases in coordination with the hydrodynamics and upstream reservoir management submodels. The phases for Delta Water Operation actions are: (1) immediate response (during flooding), (2) flushing, and (3) limited pumping.

The operations submodel reflects the standard project operating procedures that existed in 2005 together with additional details that could be inferred from discussions with operators. In general, operations are tightly controlled by the water quality standards established by the State Water Resources Control Board (SWRCB 2000) and set forth in their Water Rights Decision 1641. Under BAU, WAM assumes that the projects would not intentionally violate a requirement of D-1641, even if the “emergency” provided a common-sense rationale for doing so.

To the extent the projects can be operated with discretion, such actions often require consultation with federal and state fish and wildlife agencies under their respective Endangered Species Act provisions. These consultations require some time to formulate a request, discuss conditions and concerns, and agree on an action. Thus, the operations submodel assumes that any action requiring consultation will not be immediately available (within hours), but will require several days for formulation of a proposed action, discussion, agreement, and implementation. Consequently, such actions will typically occur during the flushing phase. Another assumption is that consultation will generally not allow compromises of intended protections for endangered species. During the limited pumping phase, normal D-1641 provisions are assumed to be in force.

In-Delta water use is assumed to be affected only by salinity conditions at the Delta island irrigation intakes. Delta water users are generally believed to have riparian or senior water rights and therefore would not be obliged to respond to requests to suspend withdrawals, though they may cooperate voluntarily. Their responses to emergency orders are not predictable – no plan exists to issue and enforce such orders, so compliance with such orders is not part of the BAU scenario for base-case analysis.

Since the analyses for future years are to be for BAU, 2005 Delta water operations approaches and rules will remain unchanged. The one potential exception (included in the 2030 California Water Plan) (DWR 2005d) is inclusion of the proposed operable south Delta barriers (DWR and USBR 2005). It is not clear that barrier operation in a levee breach emergency would be substantially different than that assumed for the 2005 case with temporary barriers. This will be addressed if a 2030 or 2050 analysis is performed.

11.3 NET DELTA AREA CONSUMPTIVE USE

Within WAM the net Delta area consumptive water use or Net Delta Area Losses submodel (referred to herein as NDAL) determines the return flow, return flow salinity and net channel withdrawals for each island and/or groupings of islands. Net consumptive use is total consumptive use minus precipitation. NDAL and net channel withdrawals are the same as net consumptive water use, because consumptive water is supplied by either precipitation or water from Delta channels. Details on the NDAL submodel are provided in Appendix A of the Water Analysis Module TM (URS/JBA 2007e). This section provides an overview.

To represent NDAL within WAM, the Delta is divided into spatial groups. Initially the Delta is divided into five groups representing each of the major Delta flow paths as defined by the hydrodynamics (HD) submodel. Each of the 142 subareas (defined by DWR for tabulating Delta net evapotranspiration) (DWR 1995) is assigned to a group and these groupings are used to report the NDAL output to the HD calculator. Each of the subareas is assigned to an evapotranspiration group, an evaporation group, and a precipitation group.

NDAL assesses in-Delta water demands based on normal irrigation net consumptive use, breach event details, islands flooded, channel salinity, and repair progress. If an island is flooded, irrigation demand ceases, as does seepage, and return flow. No evapotranspiration occurs, but evaporation occurs instead.

When an island is repaired, seepage and return flow are restarted. Irrigation can commence as well, if the island has been pumped out and adjacent channel salinity is of appropriate quality.

For an unbreached or a repaired island, NDAL checks channel salinity calculated by the HD submodel and determines whether water quality conditions are sufficient to provide irrigation water. If water quality is unsatisfactory, irrigation does not occur until water quality conditions become satisfactory.

The NDAL submodel includes the ability to read and incorporate climate changes in the form of Delta area precipitation changes, temperature increases, and carbon dioxide concentration increases. Precipitation increases result in a corresponding decrease in NDAL. The opposite is true for precipitation decreases. Temperature increases would increase evaporation and plant transpiration. Carbon dioxide increases, on the other hand, are believed to decrease water use for transpiration (JBA 2006a, 2006b) and will thus dampen the effect of future temperature increases. A summary of available information on future changes in Delta area precipitation, temperature, evapotranspiration, evaporation, and carbon dioxide is presented in Appendix G of the Water Analysis Module TM (URS/JBA 2007e).

11.4 UPSTREAM RESERVOIR OPERATIONS, TARGET EXPORTS, AND DELIVERIES

Depending on the severity of the levee breach scenario, the management of upstream and south of Delta reservoirs may be substantially altered. A small event, like Jones Tract, may require only slight modifications. But in a larger event, a prolonged period may occur with reduced or no pumping and an associated need to ration south-of-Delta supplies. Managed Delta inflows will also be needed to provide flushing and the additional Delta outflow to maintain water quality.

After adequate flushing is achieved, the quantity of inflow required (simply to maintain water quality) will include normal Delta outflow and an increased amount based on the larger tidal prism due to tidal flow into and out of unrepaired, flooded islands. Finally, when limited export pumping can be reestablished, additional Delta inflow will be needed to provide the water that is to be pumped plus both the normal and increased carriage water needed to maintain water quality.

Details on this submodel are presented in Appendix C of the Water Analysis Module TM (URS/JBA 2007e). This section presents an overview.

The reservoir management submodel makes emergency reservoir operating decisions related to the levee breaches to balance the amount of water released for Delta inflow (while the emergency and repairs progress) with the need to conserve water for other and future uses. For reservoirs south of Delta, this effort means balancing deliveries to respond to water users' needs with the need to conserve water in south-of-Delta reservoirs in case the disruptions last longer than expected or encounter dry or critical years. For reservoirs north of Delta, this effort means balancing releases to reestablish through-Delta conveyance with the need to conserve in upstream reservoirs, so that other needs can be served, drought protection is provided and, when export pumping is reestablished, water is available to pump.

The basic approach used north of Delta is to receive daily requests from the HD submodel indicating the amounts of Delta inflow needed to reestablish or maintain required water quality. Separately, the HD submodel indicates the extra amount required to facilitate any given amount of pumping. These requests are then considered by the reservoir management submodel in light of the time of year, stored water available, the quantity requested and the projected duration of the incident (with its anticipated future requirements for extra water). A set of decision rules is incorporated into the submodel to make reasonable releases while saving enough water in storage to get through the incident and be in a position to recover toward normal operations, even encountering dry years. These daily decisions are accumulated to report monthly amounts of releases, Delta exports, and end-of-month storage.

The approach is similar for south of Delta storage. Releases may be made for Central Valley Project (CVP) and State Water Project (SWP) contractors after considering and balancing available stored water, anticipated incident duration, normal allocations, anticipated limited pumping during the incident, and the intensity of needs from the earlier cuts that are part of the incident. These water contractor deliveries are apportioned in full conformance with existing contracts. Again, the decision rules are crafted to get through the incident without implementing even more drastic cuts (due to running out of water) and then being able to rebuild deliveries in a reasonable way when pumping from the Delta is reestablished.

WAM produces time-series output for Delta exports, south of Delta water deliveries, south and north of Delta storage, and north of Delta flow and delivery changes. The figures identified in the next three paragraphs show output from a sample WAM simulation – a preliminary version of a multi-island breach case beginning in August 1992. Note that the only purposes of this simulation and the results presented are to illustrate the way WAM may react to a breach scenario and to indicate the types of water flow and storage output information that will be generated.

The figures contain traces of Delta exports for a baseline (without disruption) and for a preliminary multi-island breach case. Figures 11-3 and 11-4 show Delta exports for each month for the CVP and SWP, respectively, for the WAM simulation. Both CVP and SWP exports are halted during the flooding and flushing period after the breach and resume after 7 months.

Figure 11-5 provides plots of total (SWP and CVP) south-of-Delta deliveries with and without the breach and total delivery reductions due to the disruption. WAM allocates water to each group of contractors of the SWP and CVP based on contract priority. The total reduction in delivery is about 2.8 million acre-feet.

Figure 11-6 shows plots of south-of-Delta storage. During this model simulation, south-of-Delta storage dropped by about 2 million acre-feet.

WAM is designed to provide these types of data for each levee breach scenario that is considered. Additional example plots and more detailed discussion of the reservoir management submodel are provided in the Water Analysis Module TM (URS/JBA 2007e).

Refinements of the upstream reservoir management submodels for future years will generally be avoided in the spirit of providing a BAU analysis. Operating rules will be altered as necessary in the CalSim runs (used as input) to develop reasonable base cases. The objective will be to ensure that reservoirs are not unrealistically drawn down in the “no breaches” case used as a baseline. Follow up refinements of WAM operating rules may be required to avoid similarly unrealistic drawdowns in levee breach events. Operating rules are discussed in more detail in Appendix C of the Water Analysis Module TM (URS/JBA 2007e).

The hydrologic input to WAM may change quite dramatically for future years. WAM is designed to use CalSim input and output as the basic source of hydrologic information. For present (2005) conditions, it uses the CalSim Common Assumptions 2005 LOD simulation. For future years, WAM will need to have available future year CalSim runs reflecting changes in level of development and climate change-induced modifications to the hydrologic regime. Although little information is available beyond 2030 regarding level of development, substantial work has been performed to assess the impacts of climate change on the input hydrology (rim flows) for CalSim and the resulting impacts on amounts of water available for water supply. This work is described and summarized in Appendix F of the Water Analysis Module TM (URS/JBA 2007e). Additional work is needed for other inputs, including precipitation, temperature, carbon dioxide, and the resultant evaporation and evapotranspiration (see the Water Analysis Module TM [URS/JBA 2007e], Appendix G).

11.5 HYDRODYNAMICS AND WATER QUALITY

The challenge of modeling the hydrodynamics and water quality has been somewhat different – it has not been to balance decisions, but to have a working interaction with the water management decisions to calculate the Delta salinity resulting from these decisions in the context of the specific levee breach scenario. Very sophisticated models are already available for doing this calculation (e.g., DSM2 and the RMA Bay-Delta Model). However, it takes hours to days of real time for these models to simulate a large-scale levee breach event, so it is not feasible to use them in a fully interactive mode or for each of several thousand scenarios.

A simplified hydrodynamics/water quality submodel has therefore been developed as part of the WAM. It is described in detail in Appendix D of the Water Analysis Module TM (URS/JBA 2007e) and its calibration is described in Appendix E of the Water Analysis Module TM (URS/JBA 2007e). The following summarizes the approach that has been implemented:

- Use existing physically based numerical models (RMA Bay Delta Model and TRIM/UnTRIM 3D models) to explicitly evaluate hydrodynamic, salinity, and other water quality impacts for a limited number of specific breach events, as well as to characterize the dynamics of the system.
- Analyze scenario simulations conducted using existing multidimensional models to estimate dispersion coefficients that quantify the strength of salt intrusion and mixing processes.
- Create a new tidally averaged flow and salinity transport model using a one-dimensional network approximation reaching from the central San Francisco Bay to the upstream limits of the Delta to rapidly evaluate salinity impacts of levee breach events and interact with the water management decision-making component of WAM.

The primary challenge in developing the simplified hydrodynamic/water quality model has been to represent enough of the physics to provide sufficient accuracy while maintaining the computational speed needed to simulate many thousands of levee breach events. The primary outputs of the WAM are monthly average quantities including export volumes and salinity, and in-Delta salinity at selected locations. Therefore, it is not necessary for the simplified model to explicitly represent the flow and transport on the tidal time scale or variations in flow velocity or salinity concentrations across a channel cross section.

The simplified model is therefore a one-dimensional, tidally averaged transport model. This type of model considers net flow (advection) and tidal mixing (tidal dispersion, turbulent diffusion, and vertical stratification and mixing) relations derived from full dynamic models of the system. The simplified model then interacts with the water management component of WAM during the course of simulation, both providing input to the water management decision-making component and receiving calculated inflows and exports. Figure 11-7 illustrates the basic conceptual structure of the simplified model.

Figures 11-8 and 11-9 provide samples of daily outputs from the HD model for an example of a multi-island levee breach event occurring in various years (assuming July 1 of each year) and in various months (for 1993). The figures indicate that the WAM HD submodel is capable of showing dramatic increases in salinity (at Jersey Point) as expected from an event of substantial magnitude. It also shows that the HD submodel will respond to the different Delta inflows and salinity conditions that prevail with different types of water years and different months during a year.

More details on the calibration and performance of the HD submodel are provided in Appendices D and E of the Water Analysis Module TM (URS/JBA 2007e). The WAM module, including both Delta HD simulation and reservoir/export operations, completes a 5-year simulation of multiple island breach events in about 90 seconds on personal computers.

Appendix E describes intensive calibration efforts for the normal (non-breach case for October 1991 through September 2003 using “dayflow” boundary conditions – all the inflows and outflows for the Delta and their associated salinities. Five additional in-Delta locations with important channel connections were also used in the calibration. The HD submodel calculations of salinity (EC) at the SWP and CVP export locations (for no breaches) are generally within about 15 percent of peak summer observations. Figure 11-10 provides an example (from the Water Analysis Module TM, Appendix E) of WAM-computed EC at the SWP intake as compared to “dayflow” data from the calibration period.

A large number of comparisons of calculated versus observed data for stations other than those used in the calibration are presented in Appendix E. Also, the 50-breach (20-island) simulation by the RMA Bay Delta model (JBA 2005) was used to calibrate dispersion between channels and flooded islands for breach cases. Data from the Jones Tract breach incident were used to perform a limited verification. As a DRMS risk assessment tool, WAM HD has met the requirements for computational speed, simulation capability and accuracy for present (2005) conditions.

The hydrodynamics and water quality model will reflect future changes in two substantial ways. First, the sea-level rise attributed to a future analysis year will be incorporated. This will change Delta hydrodynamics and may require recalibration of the dispersion coefficients used in the simplified hydrodynamics model. Second, when a levee breach with island flooding occurs, a larger volume will be flooded because of both the higher flood water level (higher sea level) and the lower island surfaces where subsidence has occurred.

11.6 WAM SUMMARY

Overall, WAM has achieved the two objectives set forth in Section 11.1.2. It efficiently calculates the water quantity and quality information needed to estimate the economic and environmental consequences of a wide variety of levee breach scenarios, each of which may occur during dramatically different seasonal and hydrologic conditions. These capabilities are illustrated in Figures 11-11 and 11-12, which show WAM results for five seismic scenarios used in the Draft Phase 1 Report, issued in June 2007 (URS/JBA 2007b). Cases 2 through 6 are respectively:

- Case 2 – three flooded islands with no repairs needed for other, unflooded islands
- Case 3 – three flooded islands with substantial repairs needed for unflooded island causing delays in initiation of repairs for the flooded islands
- Case 4 – ten flooded islands, no others damaged
- Case 5 – twenty flooded islands, others damaged and repaired first
- Case 6 – thirty flooded islands, others damaged and repaired first.

Figure 11-11 shows the export deficit at the time pumping can be resumed as calculated by WAM for each scenario, assuming different event initiation times. Because of the need to limit the width of the figure, only 154 event initiation times are shown, covering the first of each month from January 1986 through October 1998. The calculations were actually performed for the first day of each month from January 1923 through October 1998 (910 event initiation times), as indicated by the exceedance probability plot shown in Figure 11-12. This demonstrates the abilities of WAM, both to address a wide variety of hydrologic conditions and to cover the spectrum of available hydrologic data with computational efficiency.

11.7 OTHER WATER QUALITY IMPACTS

In WAM, water quality conditions are represented by salinity, but other water quality measures can potentially be modeled in future versions. As with salinity, other water quality parameters have concentrations that are influenced by the volume of water required to fill the islands, tidal mixing, dispersion, dilution, freshwater inflows, flushing, water exports, and management decisions. These conditions are already modeled by WAM.

One of the potential water quality impacts for water exports is from increased treatment costs due to organic carbon released from flooded islands with predominately organic soil. Organic carbon can act as a disinfection byproduct precursor. Such byproducts include carcinogens. As part of the water treatment process, excess organic carbon can be removed before chemical disinfection and, thus, reduce the prospective creation of disinfection byproducts. However, this may require capital facilities that are not already in place when the emergency occurs, and a significant operating cost even when the facilities are online.

In contrast to salinity, sources for other potential water quality pollutants can include water inputs from the river/Delta/Bay system as well as benthic sediments, suspended sediments, island stockpiles, or accidental contaminant releases from the Delta islands. Chemical pollutants have the potential to impact in-Delta water use, ecosystems, and water exports. The location, quantities, and chemical composition of potential toxics located on Delta islands are not extensively inventoried.

The locations of some of the potential sources of toxics can be seen on Figures 11-13 and 11-14. Figure 11-13 shows toxic sources in the Delta complied from EPA Envirofacts database, from the Department of Toxic Substances Control EnviroStor database, and from narrative information included in the Land Use and Resource Management Plan for the Primary Zone of the Delta (Delta Protection Commission 2002). Envirofacts contains the toxic release inventory and a list of facilities that are hazardous waste generators, transporters, or NPDES permit holders. EnviroStor inventories cleanup sites including federal superfund sites, state response sites, and voluntary cleanup sites.

Figure 11-14 shows the location of all of the oil and gas wells and production fields in the Delta. Although safeguards and controls exist for toxic material storage containers and oil and gas extraction wells, these controls are not necessarily designed for an extended submergence after a period of stress. Additional information regarding potential water quality pollutants on Delta islands is provided in Section 12.

Potentially, future versions of the WAM can use transport modeling and particle tracking to model the dispersion of known sources of toxic chemicals.

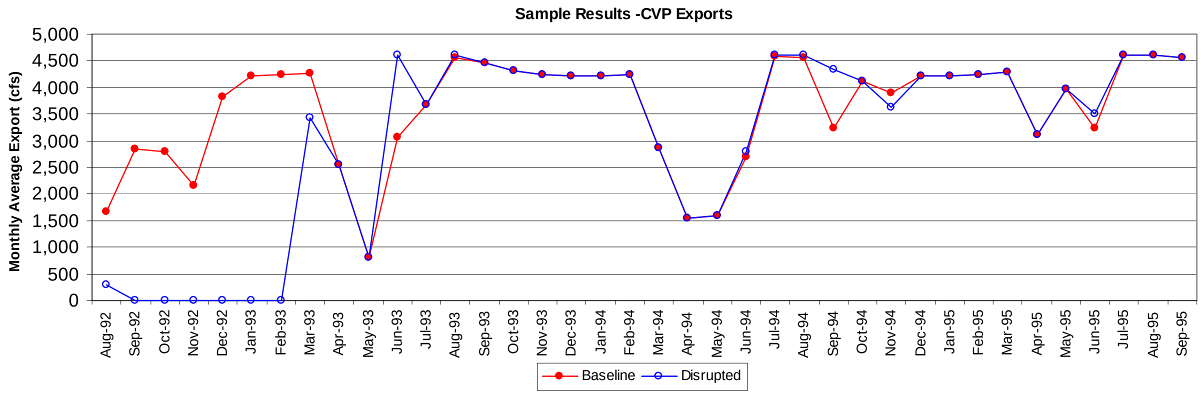


Figure 11-3 CVP Exports

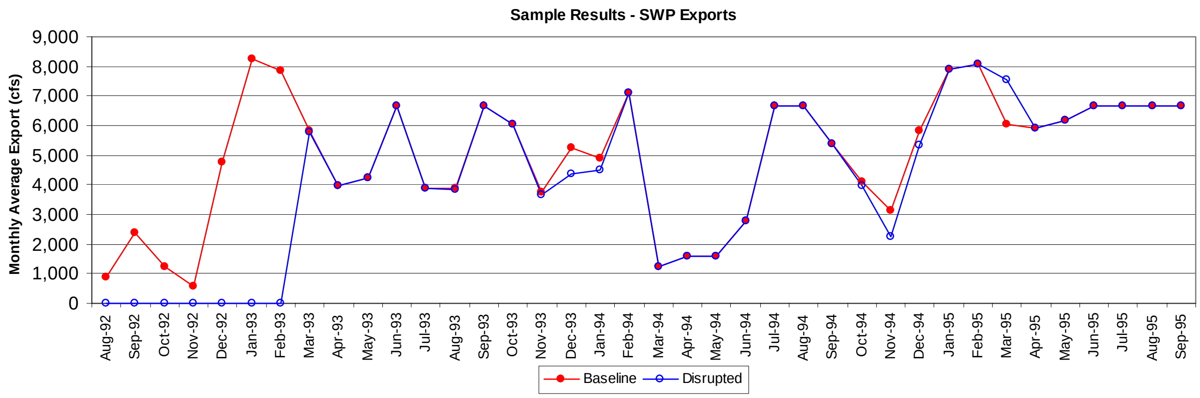


Figure 11-4 SWP Exports

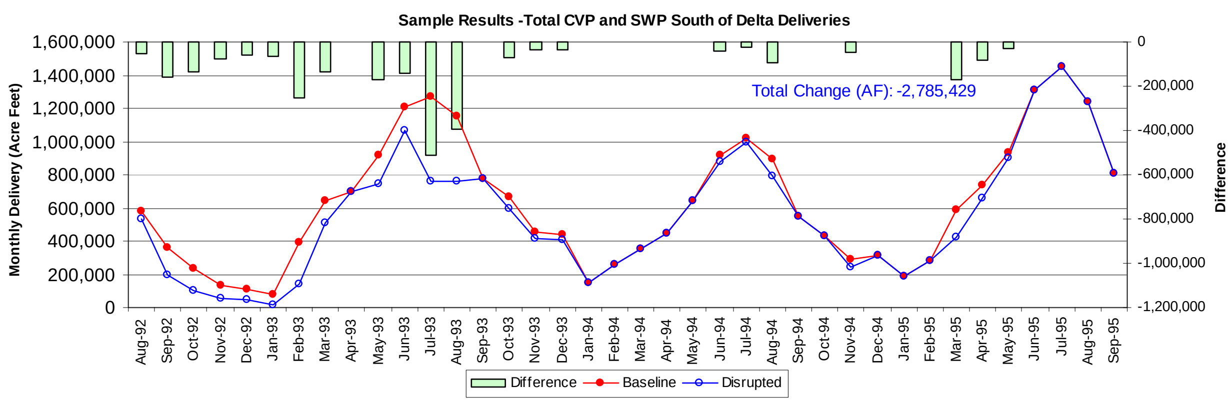


Figure 11-5 Total South-of-Delta Deliveries

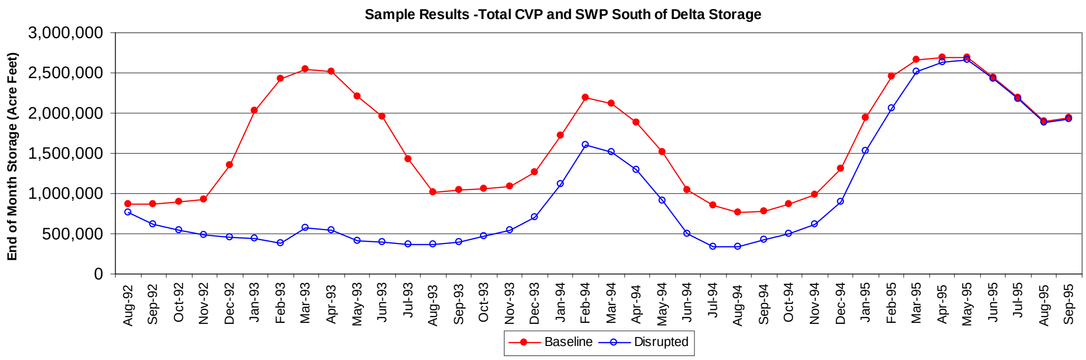


Figure 11-6 Total South-of-Delta Storage

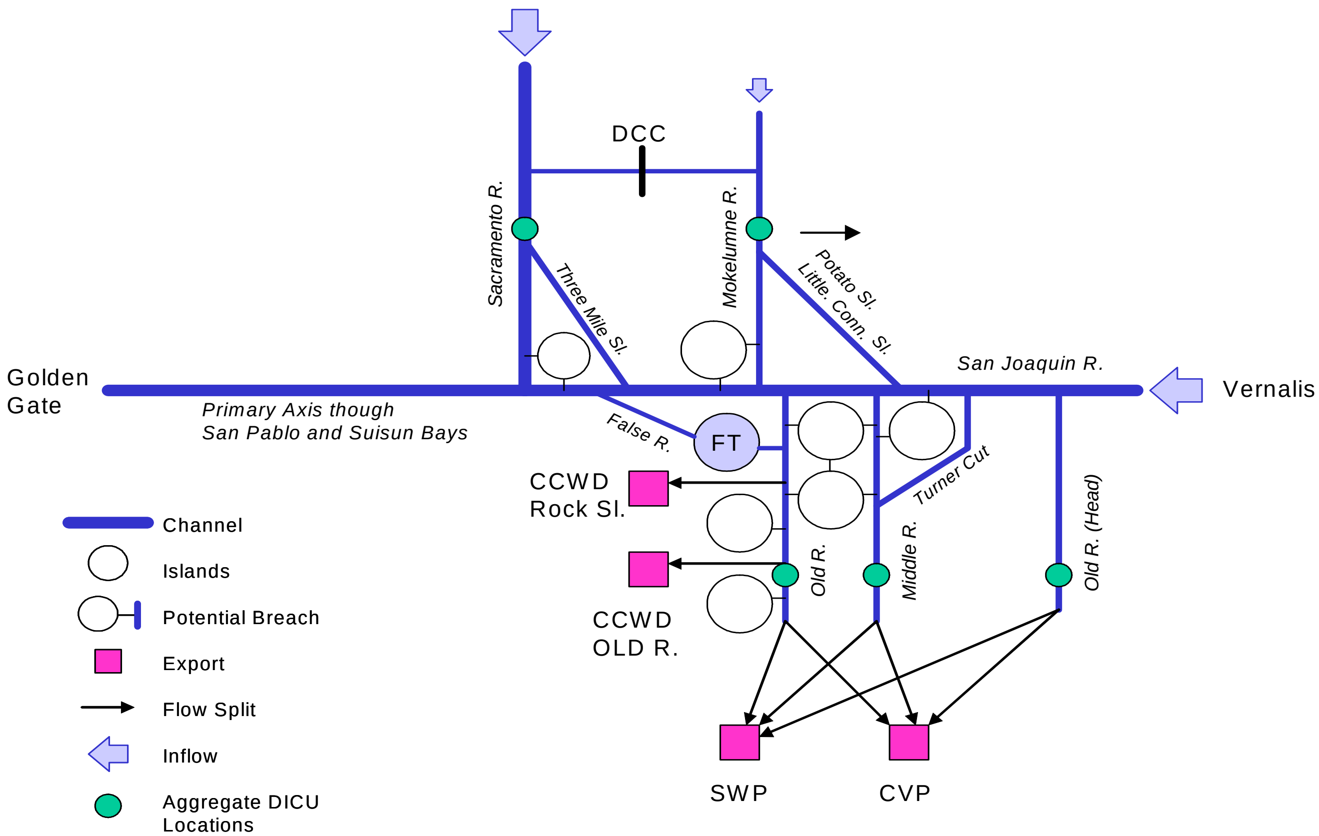


Figure 11-7 Simplified Hydrodynamic/Water Quality Submodel Schematic (showing example islands only)

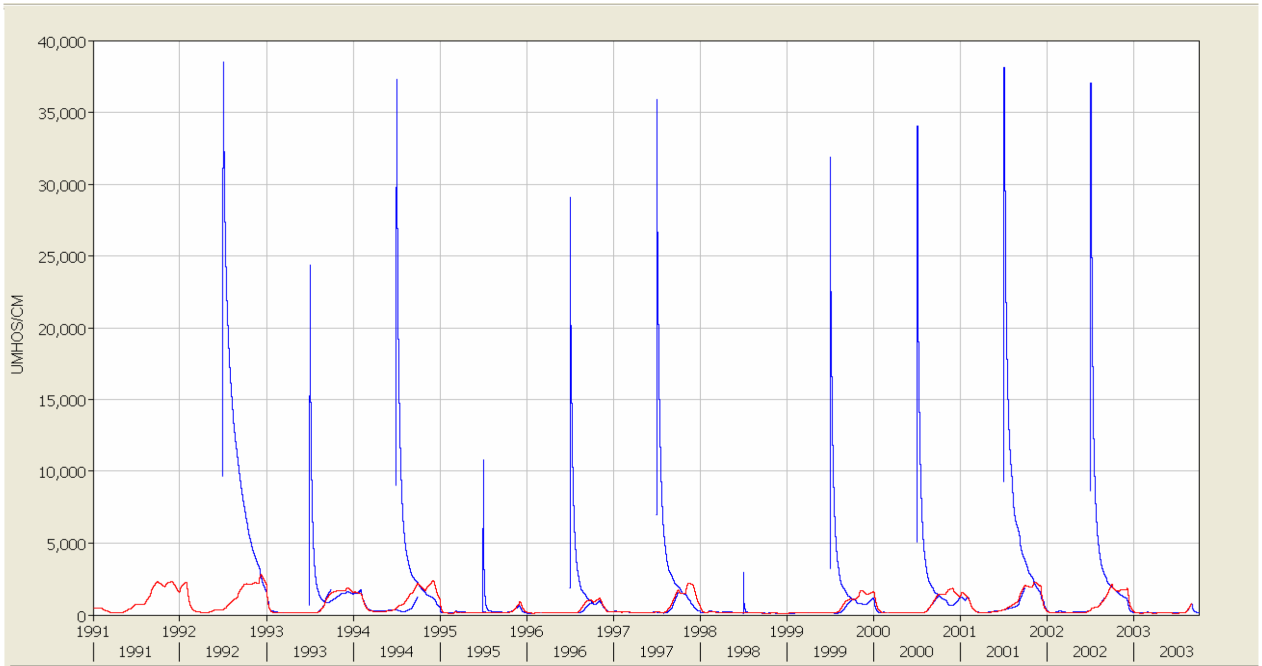


Figure 11-8 WAM HD Calculation of the Jersey Point Salinity Response to a Multi-Island Levee Breach Event Occurring on July 1 in Various Years

(Note: red line shows salinity without levee breaches; blue lines show salinity with levee breaches at alternative times.)

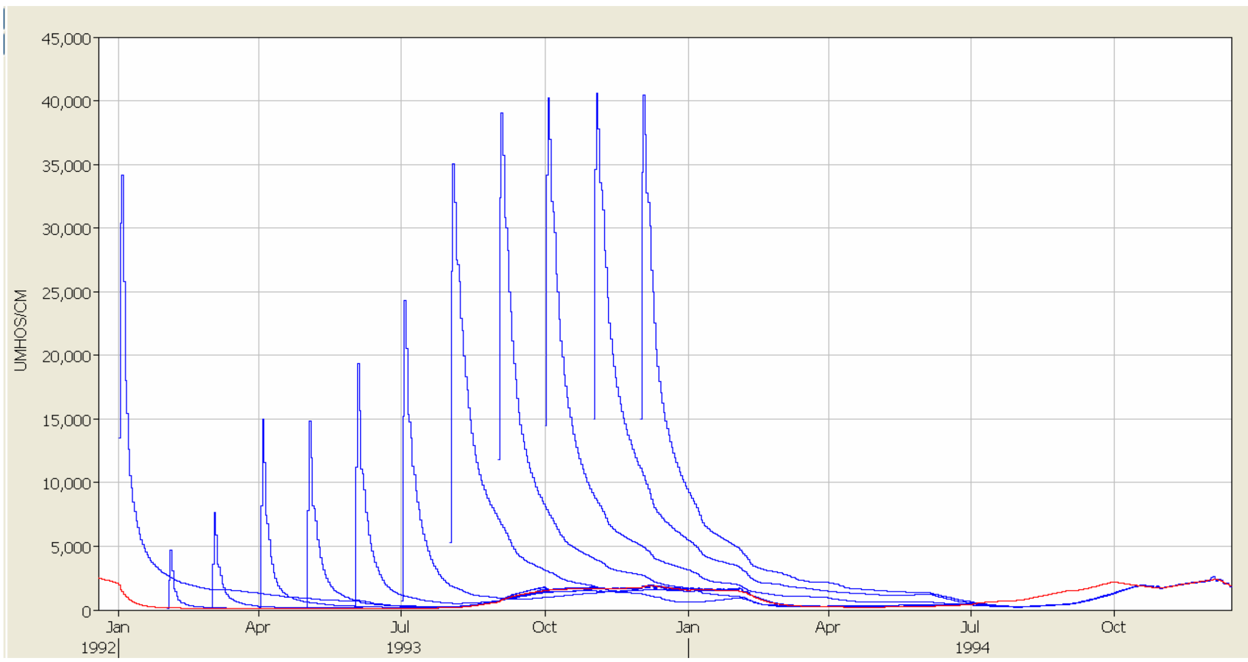


Figure 11-9 WAM HD Calculation of Jersey Point Salinity Response to a Multi-Island Levee Breach Event Occurring (Alternatively) on the First of Each Month During 1993

(Note: red line shows salinity without levee breaches; blue lines show salinity with levee breaches at alternative times.)

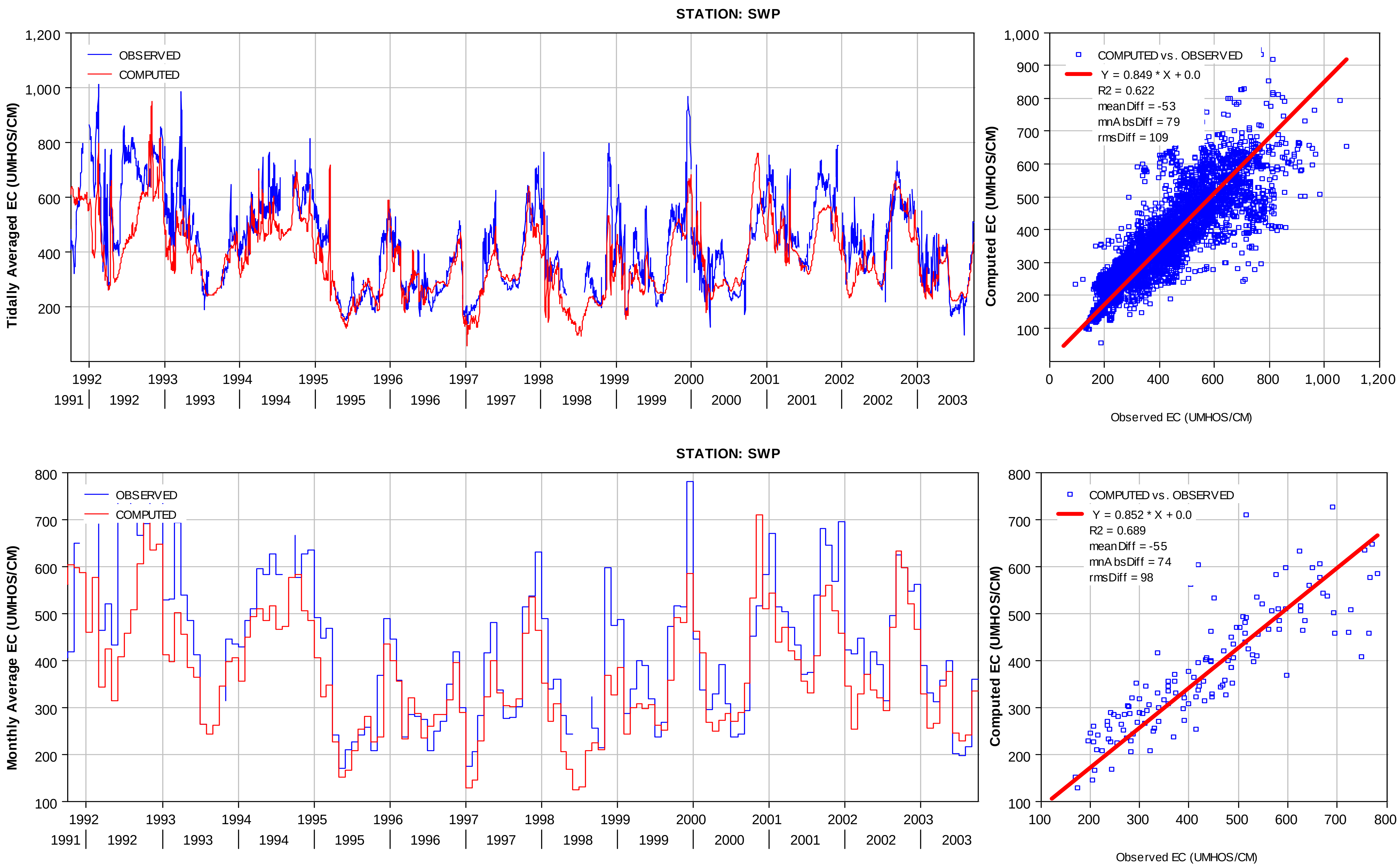


Figure 11-10 WAM-Calculated Tidally Averaged and Monthly Averaged Salinity (EC) at Station SWP Export – Calibration to Dayflow Boundary Conditions

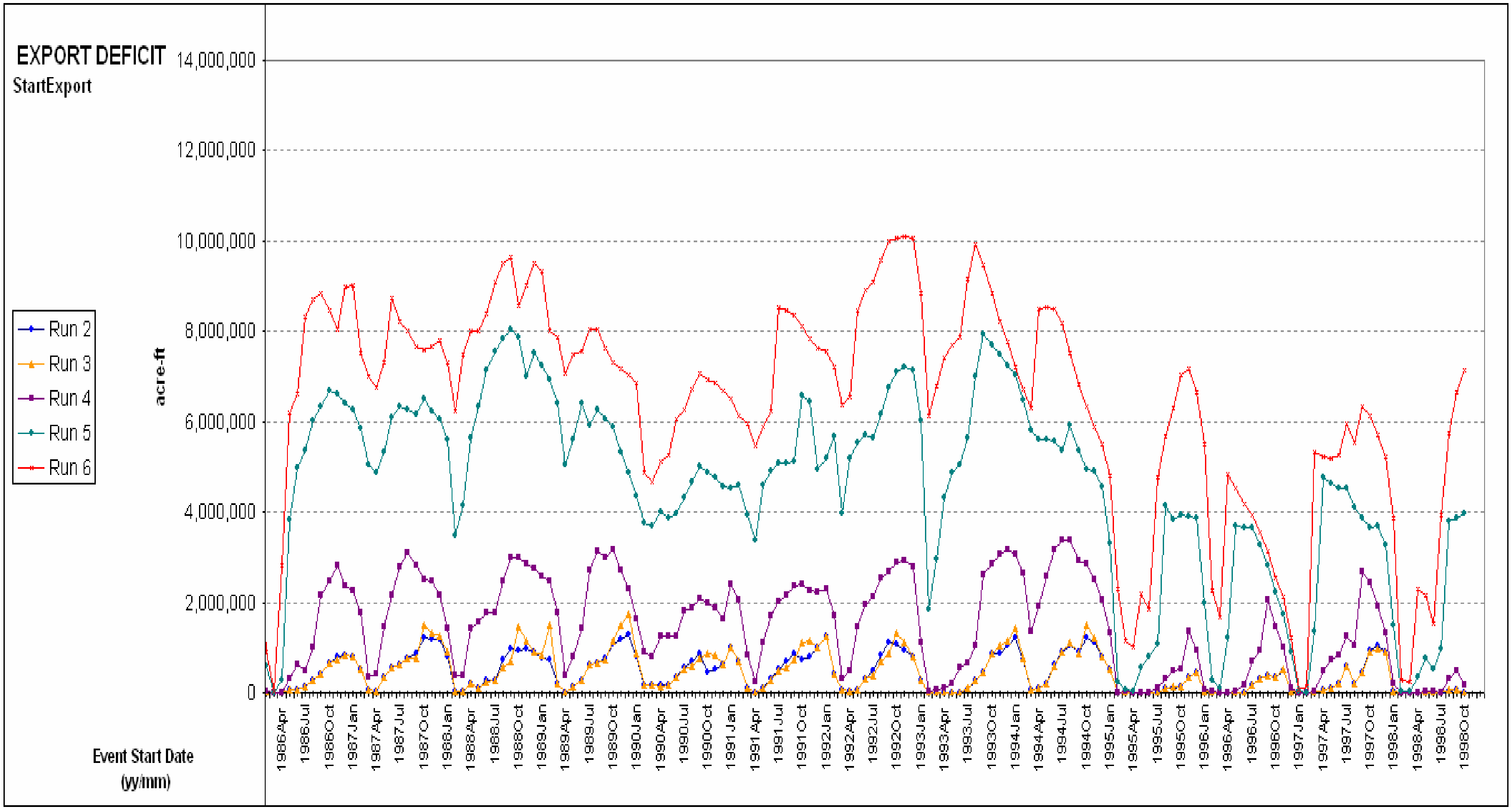


Figure 11-11 Export Deficit at Time Exports are Initially Resumed Based on Starting Breach Events on the First of Each Month from January 1986 through October 1998

Risk Analysis Event Seismic Sequences 2 through 6 as Defined in Phase 1 Draft Report (URS/JBA 2007b)

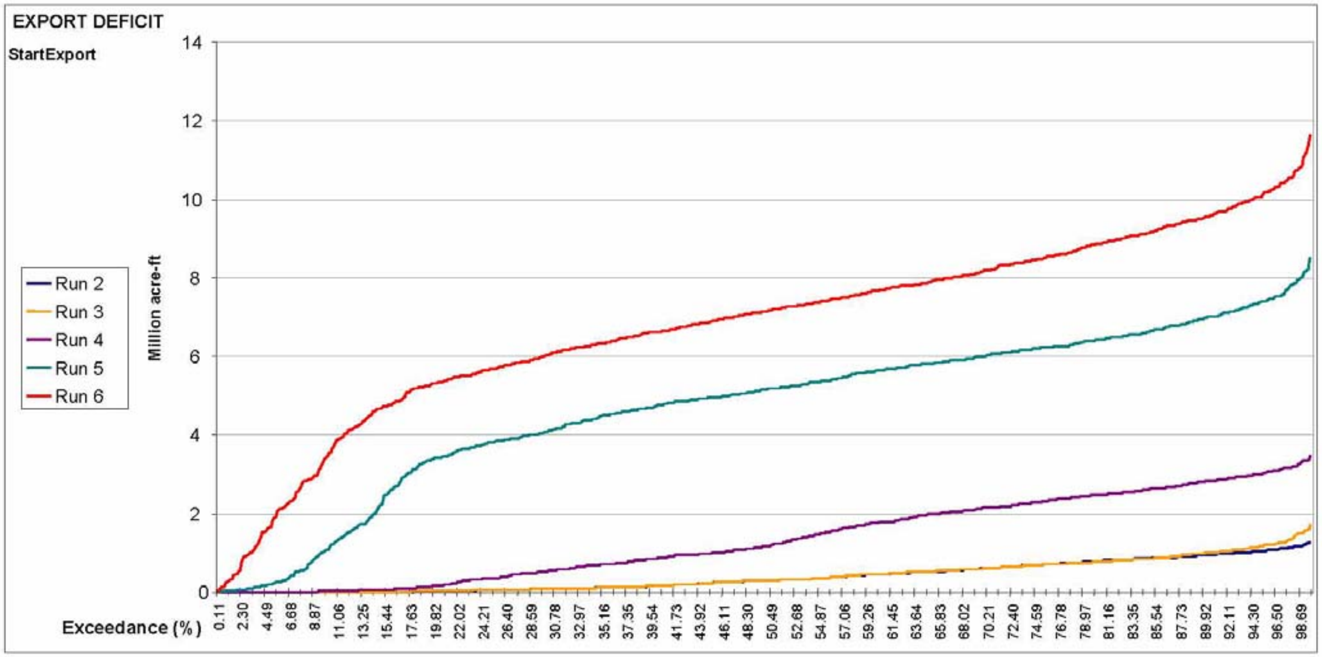


Figure 11-12 Exceedance Probability of Export Deficit at Time Exports are Initially Resumed Based on Starting Breach Events on the First of Each Month from January 1923 through October 1998

Risk Analysis Event Seismic Sequences 2 through 6 as Defined in Phase 1 Draft Report (URS/JBA 2007b)

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Toxics\DRMS_toxics_map.mxd Date: 3/6/2007 5:55:39 PM Name: akkeele0

Type of Toxic Area

- Chemical Storage
- Clean-up
- NPDES
- Small Generator
- Superfund
- Toxic Release
- Transporter

Wastewater and Biosolids Disposal

Dredge Materials Disposal

Analysis Zone

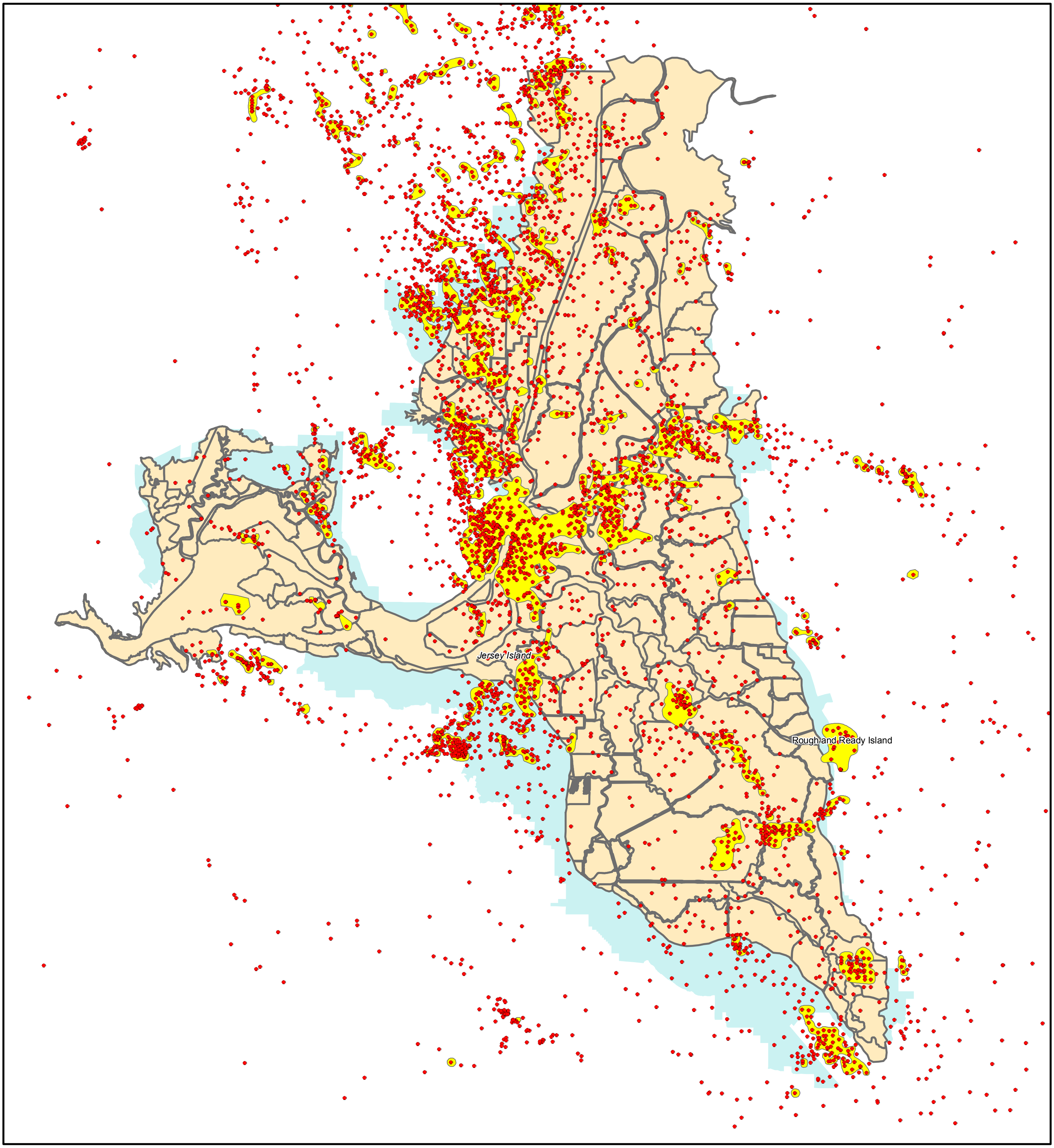
FEMA 100-year Floodplain

Legal Delta and Suisun Boundary

0 2 4 8 Miles

N

URS	DRMS / 26815621	Toxics Known in the Delta	Figure 11-13



URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Toxics\DRMS_gas_oil_data.mxd Date: 3/6/2007 5:55:39 PM Name: akkeele0

Analysis Zone

FEMA 100-year Floodplain

Legal Delta and Suisun Boundary

Gas and Oil Production Fields

Gas and Oil Wells

0 2 4 8

Miles

N

URS	DRMS	Gas and Oil Facilities in the Delta	Figure 11-14
	26815621		